GazeArchers: Playing with Individual and Shared Attention in a Two-Player Look&Shoot Tabletop Game

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ABSTRACT
Gaze can complement touch on surfaces for fast target selection and occlusion-free input. In this work, we look beyond single-user application of gaze and touch and explore how gaze can be leveraged for collaborative use. We present the design of a two-player shooter game in which targets are gaze-aware and able to react differently to attention by one of the players versus shared attention of both players. The gameplay, evaluated in a study with 14 users, encourages users to adopt different strategies switching between individual and shared attention to achieve their collaborative goal.

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User Interfaces: Input devices and strategies

Author Keywords
Tabletop; eye gaze; multi user; joint attention; game.

INTRODUCTION
Eye gaze interaction is increasingly investigated in settings beyond the lab in both mobile and public display settings [3, 10, 19]. Users naturally direct their gaze to objects of interest, and they can reach faster and further with their eyes than with their hands. Recent work has shown that gaze can be combined with touch to leverage the respective strengths of the two modalities, using gaze to point at targets and touch to confirm selections and to manipulate selected targets [7]. This has been shown to be highly effective for remote target selection on large displays [14], content transfer between remote and handheld devices [17, 18], redirection of touch input to reduce physical effort [9, 10], and seamless switching between direct and indirect touch on surfaces [7]. However, the advantages of gaze have only been explored for single-user applications, while interactive surfaces naturally afford collaborative use.

We propose that gaze offers distinct opportunities for collaboration on shared displays. Eye trackers are limited to follow a single user's gaze, and as a consequence gaze has remained underexplored for multi-user contexts. However, our use of gaze in everyday interaction is highly social. We follow each other's gaze, have *shared attention* when we focus on the same object, and establish *joint attention* when we are jointly aware of attending to the same object. These mechanisms are fundamental for how we communicate and collaborate with each other. In this work, we present a first exploration of how social gaze usage can be embraced for multi-user interfaces on surfaces. For this purpose, we have designed a two-player tabletop game in which we 'play' with individual versus shared attention.

MUM '16, December 12-15, 2016, Rovaniemi, Finland.

DOI: http://dx.doi.org/10.1145/3012709.3012717

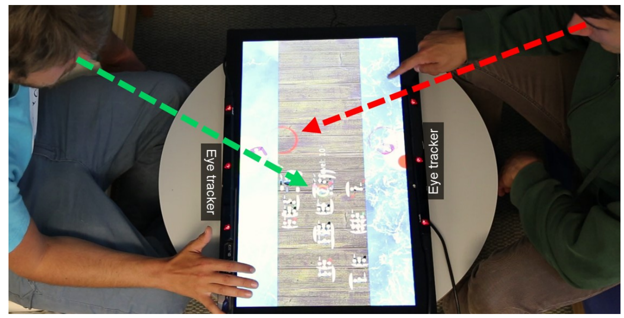

Figure 1. GazeArchers is a two-player shooter game in which players select targets by gaze (indicated by the arrows). Some targets can be eliminated by individual attention, whereas others require users to coordinate their attention.

GAZEARCHERS
GazeArchers is a collaborative two-player shooter game. The two players are placed opposite each other at a tabletop, and play as archers who defend against incoming footmen units (Figure 1). The players use their gaze to aim at footmen, and tap on the surface to release arrows. This game setting allows us to explore individual versus shared attention, as users rapidly shift their attention from footman to footman.

From a system's perspective, we can design gaze targets to react differently depending on whether they are looked at by only one of the players, or by both players at the same time. In our game, we explore this by giving footmen different levels of gaze-awareness (Figure 2):

- **Normal Footman**: The normal footman runs along without any abilities, and is meant to initially learn the game. Any user can look at this target and tap to defeat it.

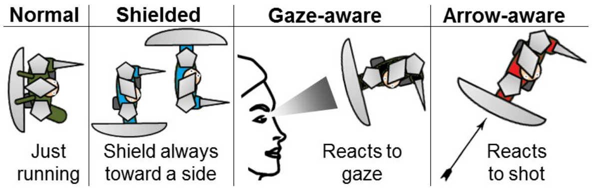

Figure 2. Four footmen types

- **Shielded Footman**: Shielded footmen have a shield that is always oriented towards one side. Only one user, who sees the footman's unprotected side, can attack this footman.
- **Gaze-aware Footman**: Gaze-aware footmen dynamically react to a user's gaze. If a user looks at this footman, it will hold its shield towards this user. This will deflect any arrows coming from this user (but not the other side's user). The shield is held in this direction until the user looks away. If another user looks at it during this time, it will keep the shield toward the original user.
- **Arrow-aware Footman**: Arrow-aware footmen react dynamically to a user's arrow. If a user only looks at it, no reaction occurs. If a user fires an arrow at this footman (look + touch), it holds up their shield towards this user to deflect it. If a second user shoots an arrow after 500 ms, the unit will direct their shield toward the second user's side. If under 500 ms, the user can successfully hit this unit.

From the user's perspective, users can attend to the same target, or look at separate targets to achieve their objectives. In GazeArchers, we explore this with a game dynamic where some footmen can be eliminated through individual attention, whereas others require users to coordinate they attention:

- **Individual Attention**: The users notice a large amount of incoming footmen. They instinctively decide to divide the workload. As each user can see their partner's attacks by seeing their cursor, they know that both of them are working on different areas to be more effective. When both users become aware that they attack the same targets, as their gaze indications converge on the same targets, they can divide their attention to other areas for a more effective division of labour.
- **Sequential Shared Attention**: A user looks at a gaze-aware footman to attack it. This footman notices it, and holds their shield toward this user (Figure 3b). The user taps to shoot arrows at this footman, but as the arrows get deflected, they shout: "come help me, this one is tough!". Their partner looks at this footman, establishing joint attention, sees that the shield is directed toward the opposite — and defeats this footman from its unprotected side (c).
- **Simultaneous Shared Attention**: A user attacks a arrow-aware footman, but it suddenly pulls the shield and deflects the arrow (Figure 4b). The partner then does the same, but as the arrow flies, the footman directs the shield to this user and deflects it, too. Both users decide to attack this footman at the same time (c). As the footman cannot react to two arrows simultaneously, one arrow defeats this footman.

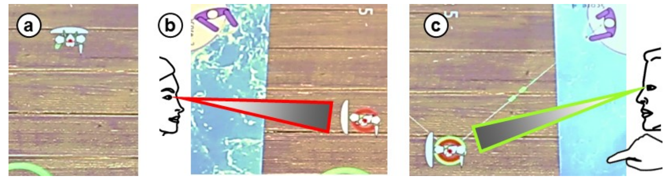

Figure 3. The gaze-aware footman runs normally when no visual attention occurs (a), but directs its shield toward the user at single attention (b). Arrows from this user are then deflected. Users need to establish joint attention toward this footman, as only a second user can attack this footman at its unprotected side (c). ***Hand icons indicate tapping*.**

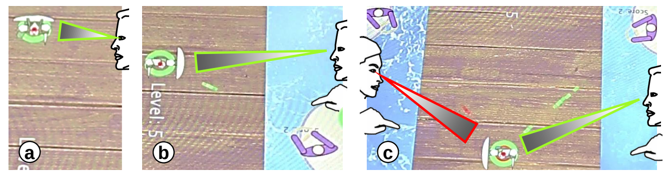

Figure 4. The arrow-aware footman runs normally in any case of visual attention (a). The shield is only drawn when an arrow is fired at the footman (b). To defeat this footman, users establish joint attention and shoot arrows simultaneously (c).

CONTRIBUTIONS

Our contributions in this work are as follows. We introduce GazeArchers that includes novel game mechanics and interaction techniques to exploit multi-user gaze awareness. We then report on a study of the user experience, conducted with 14 users playing the game in pairs. We conclude with a discussion of the initial insights gained for the design of multi-user gaze applications.

RELATED WORK

Interactive tabletops afford collaboration as multiple users can gather around the table surface, providing simultaneous user input with multi-touch and large spaces for individual and group work. Accordingly tabletops are an ideal platform for collaborative games such as board play [2], strategy, simulation [15], education [4, 12], or brainstorming [5], and we explore how eye gaze integrates in shooter games.

Combined eye gaze and multi-touch modalities has been explored in various interactive surface examples. Researchers investigated gaze selection on remote screens coupled with multi-touch gestures on a local device [9, 14, 16], and content transfer between remote and local devices [17, 18]. Pfeuffer et al. explored this combination on the same surface, to enable users both direct and indirect input possibilities in the same UI [7, 8]. These papers indicate advantages of gaze and touch input for single users, and we explore how two users' gaze can support collaborative interaction on digital tables.

Multi-user eye-tracking has been employed in remote collaboration setups for gaze awareness (the user's knowledge about where other users look at), a concept known to support workspace awareness and group coordination [6]. Applications include video conferencing [20], problem solving in software programming [13], visual search [1], and travel planning [11]. These works show promising potentials of eye gaze for collaboration, which we extend to co-located users and interaction beyond gaze awareness.

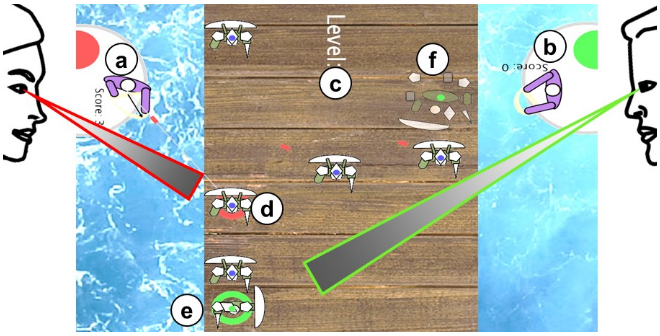

Figure 5. User interface: a typical game situation shows the users' avatars (a, b), footmen running across the bridge (c), user-targeted footmen (d, e), and defeated footman (f).

GAME DESIGN

Figure 5 illustrates a typical instance of the game. The game field is based on a bridge where the footmen run from top to bottom. The archers (the users' avatars) are located at the borders of the screen, corresponding to the actual users' physical locations. Users interact by (1) looking at a footman to aim, and (2) tapping on their side of the screen to fire an arrow toward the viewed footman. One footman can be defeated by one arrow hit.

System

Figure 1 shows the three main components: a touchscreen (Acer t272hl, 27", 1080p, 60x32.5cm), two eye trackers (Tobii EyeX, 30hz), and a laptop computer (Windows 7, 8GB RAM, dualcore i7 2.9GHz CPU). The eye trackers are mounted at the borders of the vertically laid touchscreen. Each eye tracker is directed toward the user's position, to which each user is initially calibrated. The laptop synchronises both users' gaze and touch data, and runs the game that is written with MT4J (Multitouch for Java v0.9, https://code.google.com/p/mt4j/, 02/07/2015). Users are distinguished by the respective eye tracker (for gaze data), and the location of touch data (bottom half touches correspond to the first user, and top half touches to the second user). We use a speed-adaptive algorithm to smooth gaze data; when users do fast eye movements (2250px/s, ≈70°/s visual angle) raw data is used, otherwise smoothed data is used with a moving average of the last 1s of data (30 samples). We also use target assistance to ease gaze selection: if looking 200px close to footmen, the cursor is automatically attached to the closest footman (the first/second user's cursor is green/red).

Game Progress

The game starts when users touch the designated start button in the middle of the UI. The game is based on levels that gradually increase in difficulty. The first four levels introduce the four footmen types in sequence as shown in Fig. 2, with a number of six units each level, and an initial running speed of 200px/s. From level five and above, the number of footmen and their speed increases exponentially, and footmen types are uniform-randomly selected. A level finishes when all footmen on the field were cleared. The game continues level by level until 'game over' that occurs when one footman reached the end of the bridge.

INFORMAL EVALUATION

We conducted an informal evaluation to get insights into the user experience of the game mechanics. We deployed the system for two hours in a public cafe at the local university. Fourteen users participated (7 pairs, 4F, age M=19, SD=4.96).

The procedure involved two users playing the game, and then filling out a questionnaire about the gaze indications, general dis-/likes, and which footmen type they favoured most regarding fun, frustration, and teamwork categories. Users were given a demo training session before playing the game.

Results

All users were able to quickly understand and play the game. On average, users played 1.14 free play rounds, and each round lasted 129.6s (SD=44.6s). In each round, each user defeated on average 10.1 (SD=7) normal, 7.4 (SD=4.8) shielded, 4.1 (SD=4.1) gaze-aware, and 4 (SD=4.2) arrow-aware footmen.

User ranking: The rankings indicate the user's understanding of the footmen types (Figure 6). Mixed rankings were received in the 'most fun' category, indicating individual preference for the footmen types. No user put the shielded footman in category 'least frustration'; we observed that this unit was perceived as difficult as it required a specific user to attack this unit, while other units could be defeated by both users. All users ranked one of the shielded, gaze-aware, or arrow-aware footmen in category 'most teamwork required', except the normal footman that does not require teamwork.

How did the gaze indication affect your gaming experience and strategies: eleven users found the gaze indicators useful as a cooperative game element (U8: "it helps to coordinate between players as to what targets to attack", U12: "we didn't target the same enemies and played more effective"). One user found the gaze cursor distracting, and proposed "more subtle markers" (U1).

What did you particularly like-/dislike: six users were positive about the concept and novelty of eye-based games (U1: "it is quite a cool concept and unlike any game I have played before"). Four users emphasized the cooperative game mechanics (U2: "I liked being able to cooperate with the other player to defeat the footmen"). Four users commented on eye tracking issues (U14: "it struggled to pick up my eyes"), and three stated difficulties to distinguish footmen types (U1: "it was hard to tell which footmen had which reactions").

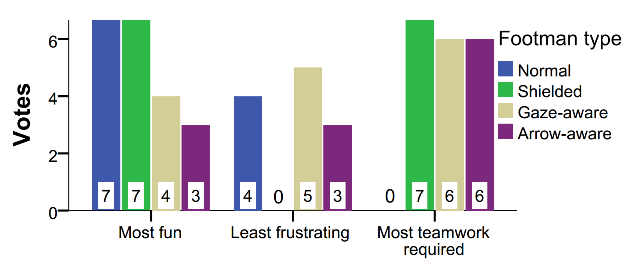

Figure 6. User preferences of the footman types

DISCUSSION & CONCLUSION

In this paper we proposed the use of individual and shared attention in multi-user interfaces and demonstrated new approaches for game design in a two-user game application. From a user's perspective, they can quickly become aware of where their partner interacts, which can be used to establish joint attention, or divide their attention to split the game's workload. From a system's perspective, game units can specifically react to the cases when no, one, or two users visually attend the target.

The rapid nature of users switching between individual, shared, and joint attention needs to be carefully integrated in the application design to avoid unnatural eye behaviour. Whether shared or joint attention occurs is unclear for a system, as only gaze on the same target is detected. There were cases where users noticed shared attention and deliberately looked away to not disturb, in other cases users drew their partner's attention to explicitly conduct joint attention, and often users accidentally looked at the same target.

Our initial system deployment showed that users can quickly grasp the novel game mechanics and are positive about how eye gaze fostered collaboration. With potential improvements in eye-tracking accuracy, the game is ready for larger installation and further user study. Future work includes extension of eye-gaze games beyond joint attention of two users, where e.g. groups of two users play competitively against each other. We also regard how individual and shared attention can be embraced in other collaborative contexts such as content sharing, interaction with tangible interaction, and tabletops that integrate personal devices such as phones.

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